Dynamic Leading-edge Stagnation Point Determination Utilizing an Array of Hot-film Sensors with Unknown Calibration

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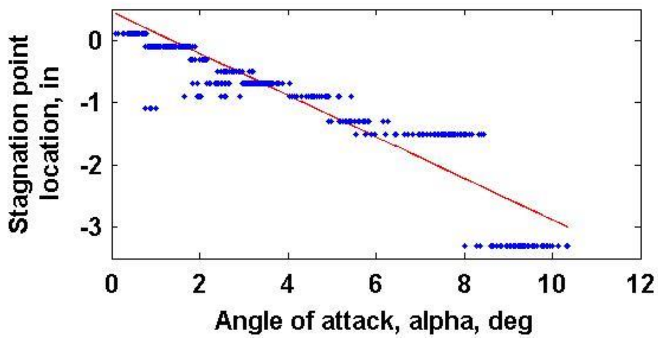
AIAA SciTech January 9, 2017

Overview

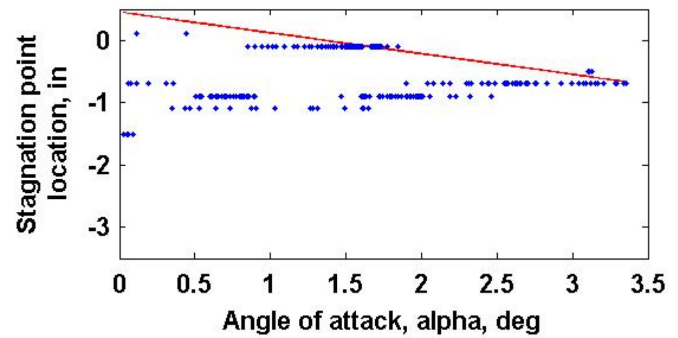
- **Aircraft: Gulfstream G-III**
- **Equipped with array of hot film sensors on left wing leading edge**
  - Stagnation point location should be straightforward
  - It wasn't
- **I Developed an algorithm that could find a moving stagnation point from the available data**

Initial Results or: What didn't work

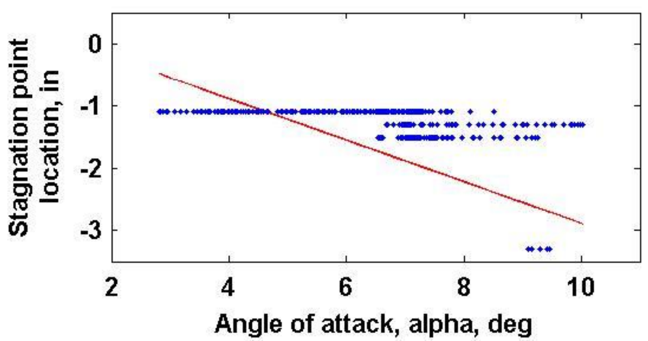
- Individual hot films are connected to constant voltage anemometry bridges, calibrated at startup against ambient temperature
- The sensor channel with lowest power consumption should be closest to the stagnation point



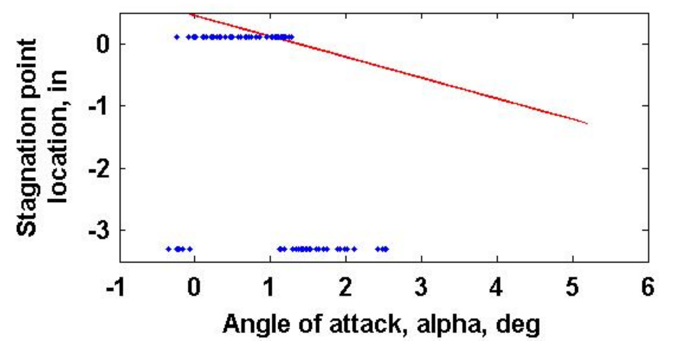
(a) Tower flyby: Acceleration at an altitude of 2,600 ft.



(b) Pitch maneuver: Mach 0.50 at an altitude of 10,000 ft.



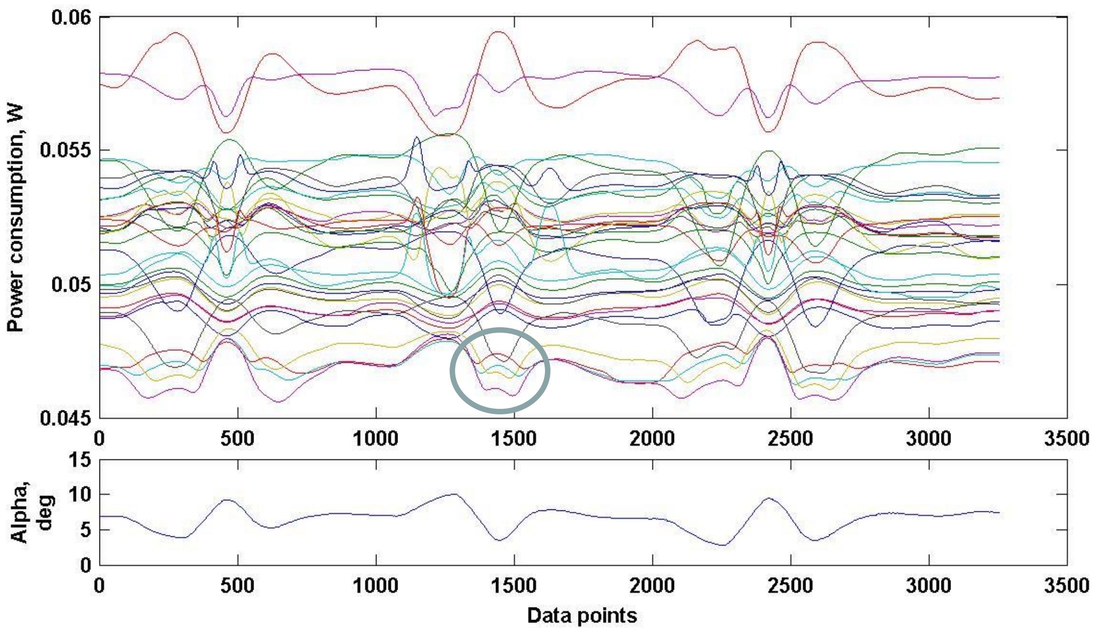
(c) Pitch maneuver: Mach 0.40 at an altitude of 30,000 ft.



(d) Pitch maneuver: Mach 0.75 at an altitude of 40,000 ft.

Digging Deeper

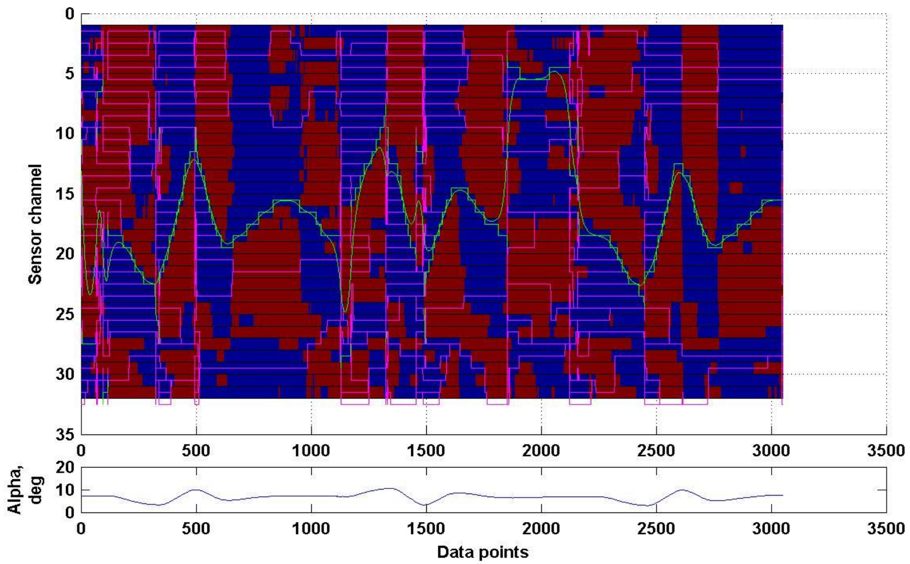
- **Because calibrations are automatic, unknown, and changing between flights, I could not recalibrate the system post flight**
- **Individual hot film sensors performed as expected**
  - Increased power consumption with acceleration
  - Power consumption changes with changes in alpha

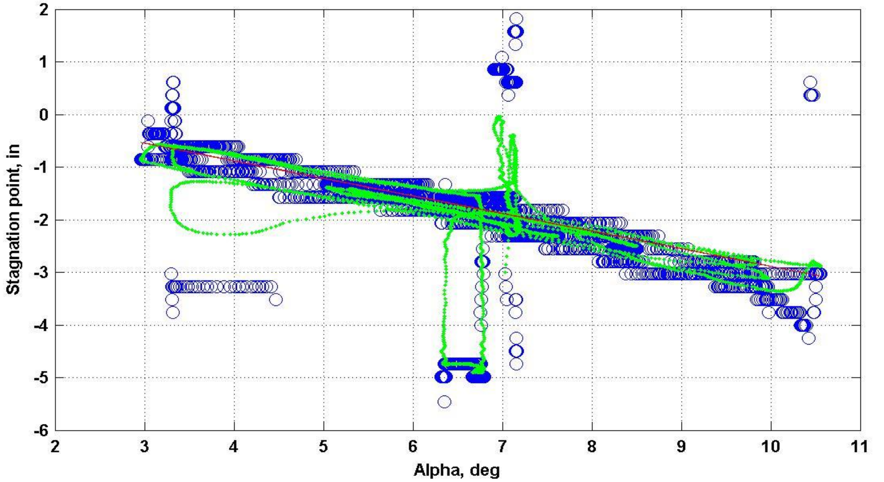


A Solution

- **Blue indicates decreased power consumption, Red indicates increased power consumption**

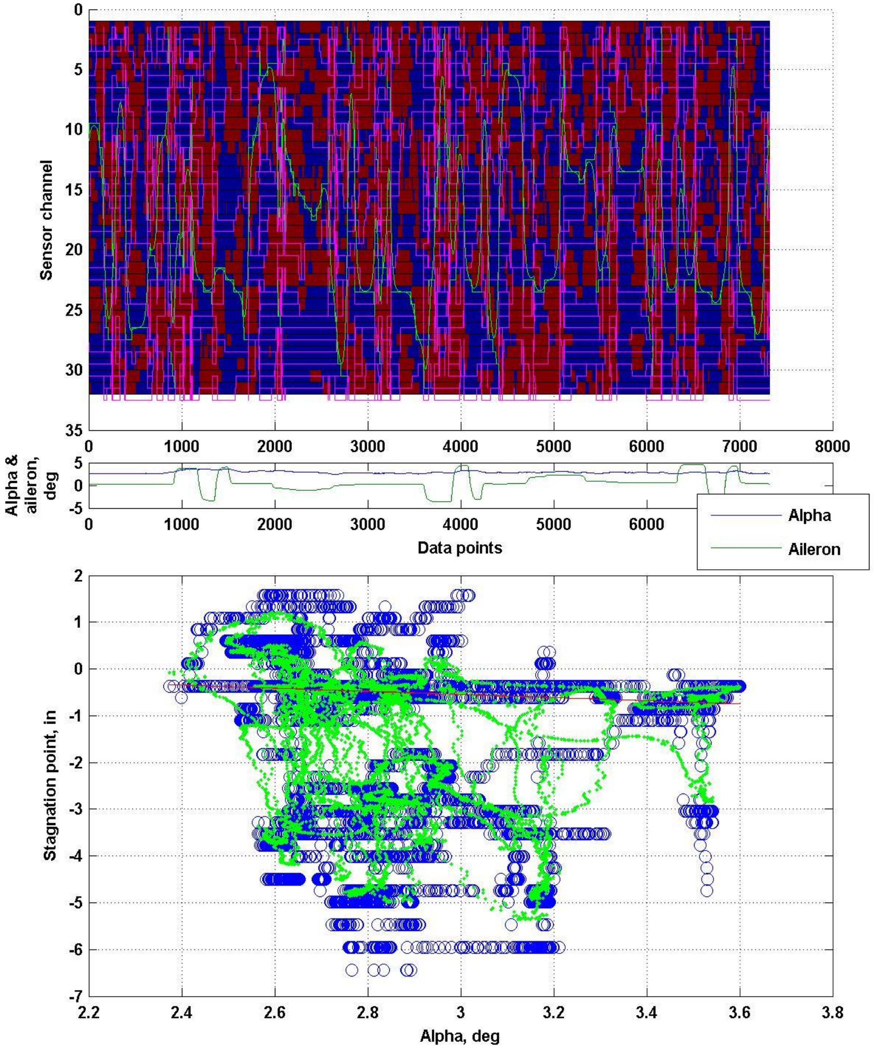
- **Dynamic behavior can tell us where the stagnation point is**
  - A sensor with power consumption that decreases and then increases could indicate the stagnation point has just crossed it
    - This gives a possible ‘edge’
  - Neighboring sensors that repeat this pattern with a time shift increase the likelihood that the stagnation point is crossing the group of sensors
    - This gives the ‘edge path’
  - Edge path with highest score (most channels feeding it) is most likely the path of the stagnation point





A Drawback

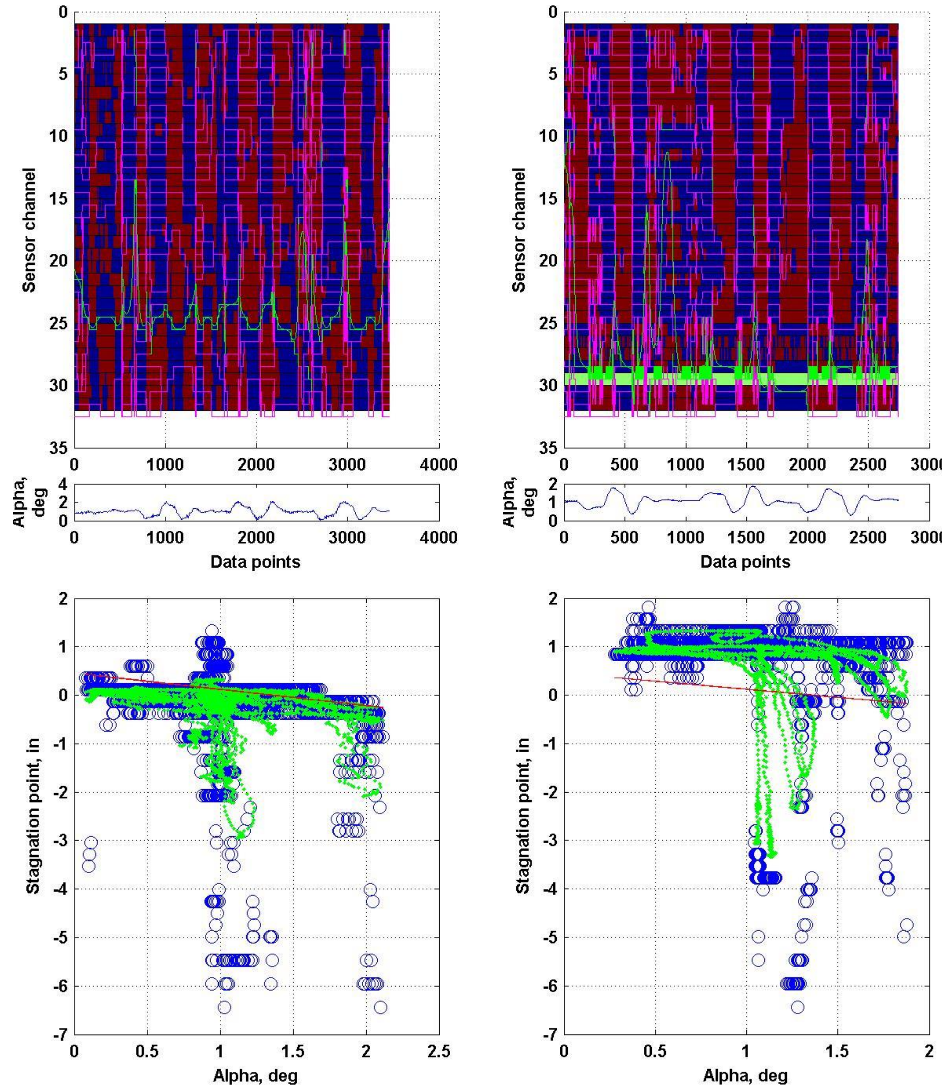
- **Algorithm requires a moving stagnation point in order to find it**
- **Algorithm resets if it can't find a good enough path**
- **For the roll maneuver at right the algorithm repeatedly restarts as there is not a strong signal to follow**
  – However, the local angle of attack changes with roll rate, enabling the algorithm to *sometimes* find the stagnation point as the aircraft responds to aileron inputs



A Challenge

- **The inherently fragile hot film sensors began failing as flights progressed**

- **Pitch maneuvers with failed sensor channels near the stagnation point produced bad results**
  - The noisy (or zero) signal from failed sensors pulled the edge path away from its true solution

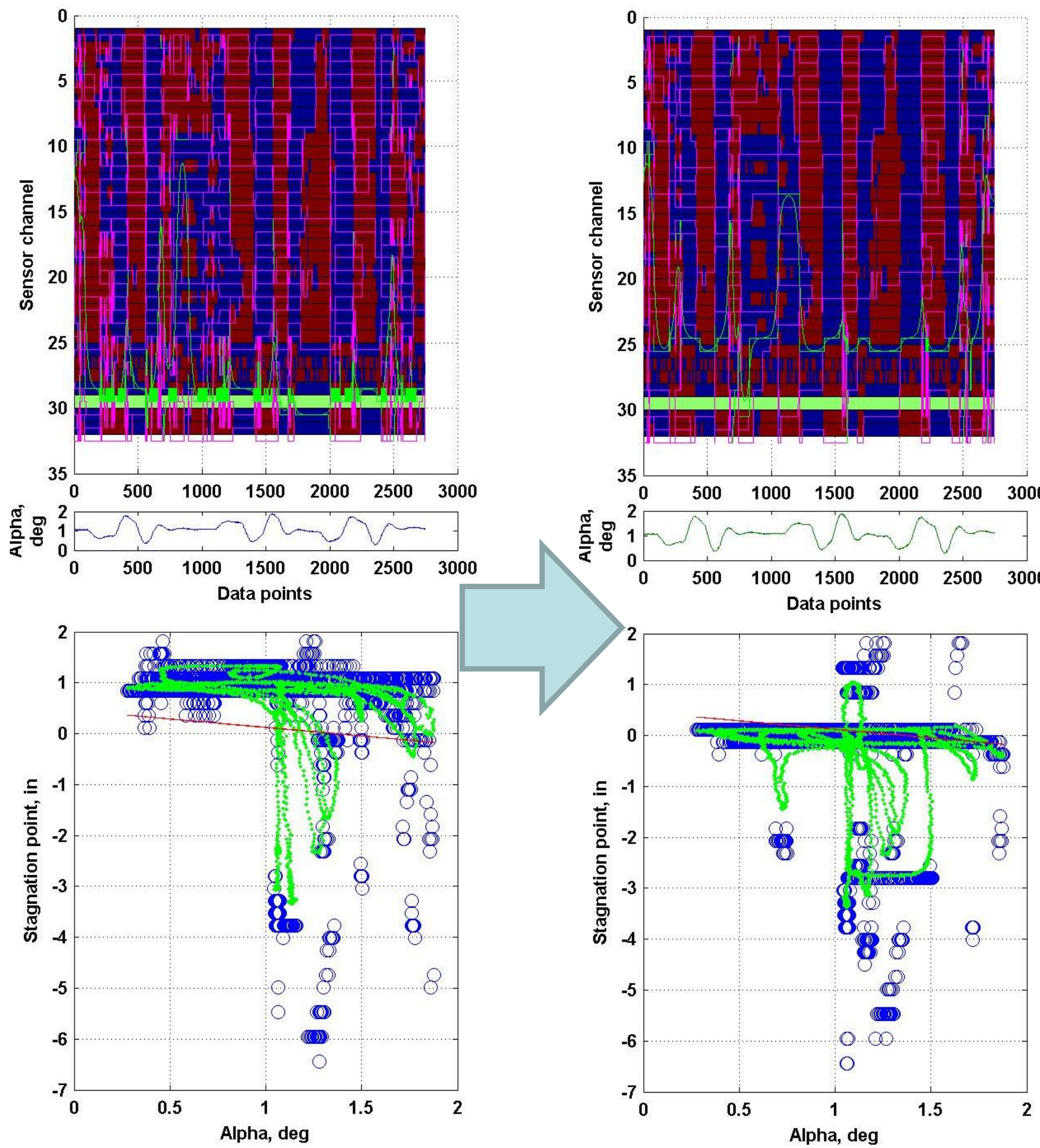


(a) All channels functioning.

(b) Channels 26, 27, and 29 failed.

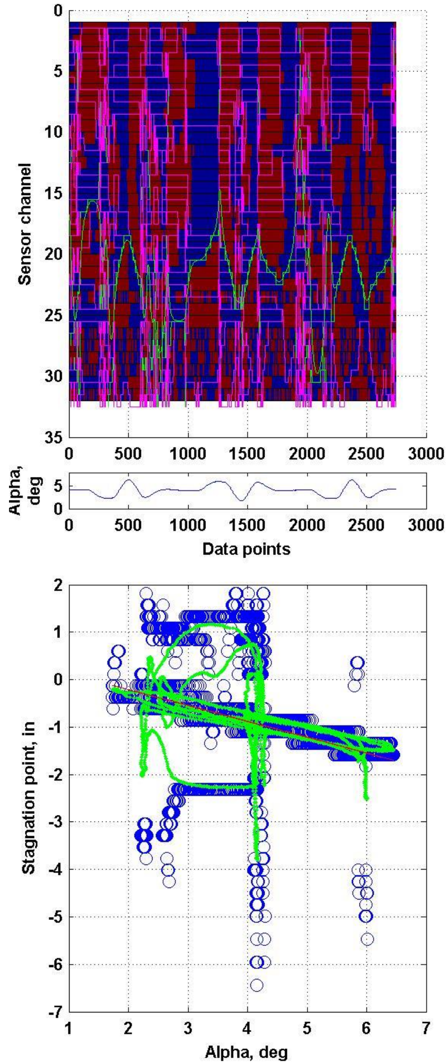
Tolerance

- **Algorithm was modified to ignore failed channels**
  - Acts as if they weren't there
  - Reduces spatial accuracy, but still yields a useful result.

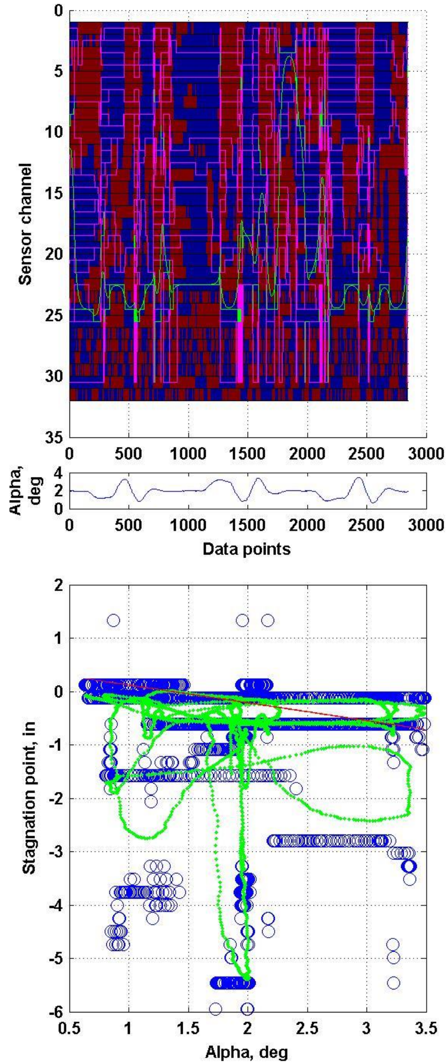


Physical limitations

- **Near end of flight series, the number of failed sensors began interfering with the ability to collect good data**
  - The stagnation point for some flight conditions fell upon a wide swath of failed sensors
  - Nearly 1.5 inches of wing leading edge had a single functional sensor



(a) Results at Mach 0.45 at an altitude of 20,000 ft.



(b) Results at Mach 0.6 and an altitude of 20,000 ft.

Questions?